Identifying and classifying surface qualities and defects of object - using video camera to store reflected images arising from sequential exposure to light from distributed sources

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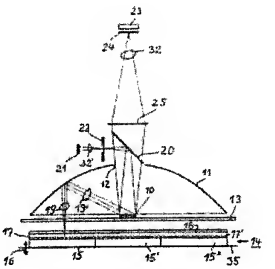
Abstract of **DE 4123916 (A1)**

The surface to be detected is illuminated from several sources (2,3) in different places. The sources illuminate the surface in sequence. The diffusely returned or reflected light at each point in the time sequence is recorded as space-time images by means of a video camera (7) with an image memory (9). The object is surrounded by an illuminating canopy whose surface light source arrangement is freely programmable w.r.t. angle and intensity stages. A further programmable light source (3) with a collimating optic (5) enables all points of a flat object surface to fulfil the reflection angle condition for the pupil of the camera lens.; USE/ADVANTAGE - Characteristics and defects of surface such as edges, textures, nicks, colour spots, mat section, waves, cracks of objects such as metal pieces, ceramic discs, metal sheets, semiconductor chips, hybrid components, SMD's and their circuits, seals. Rapid detection and classification.



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Technical field

The invention relates to a method for lightingdynamic recognizing and classifying surface features and - a defective object in accordance with the preamble of Claim 1 and apparatus for this.

State of the art

In the article of R. Malt: The use rapid lighting operations for the rugged characteristic extraction and segmentation in the industrial object recognition and quality inspection, computer science technical reports "pattern recognition 1988", DAGM
▲ top Symposion 1988, Springer publishing house, side 270 to 276, became a lighting arrangement proposed, which consists of four lighting modules::
a top illumination module for treasure-free illuminating of diffuse strewing objects, realized with a point light source, which is brought in over a divisor mirror into the observation path of rays of the CCD Matrixkamera, a touching light module for the clarification of edges and diffuse strewing surface defects, realized by or several ring lamps, a transmitted light module for the clarification of the Inner surfaces and edges from object break-throughs, and a reflection light module to the uniform, reflektorischen bright field illumination of planar or weak curved surfaces, existing from a lighting array with fresnel lens and a divisor mirror.

In the same article an other illumination system became proposed, which with the help of a in two dimensions diverted and in its intensity electrical modulated semiconductor laser during the exposure time of a single camera picture arbitrary positionable point flat sources of light, cluster and line generated, which with each picture change changed to become to be able.

Features with anisotropic strewing and reflection characteristics, like edges or scratches, supply a maximum Image contrast only if they become from a small space sector illuminated and viewed, which changes depending upon orientation of the features. The other the lightingtechnical entire solid angles must be more available, because otherwise all features or fault optimum illuminated to become to be able.

Both illumination systems mentioned sufficient therefore not yet the requirements which become provided to an inspection system, which is to detect and classify different types of error with maximum contrast with high clock rates at continuous alternate object types and object orientations.

Object of the invention

The invention is the basis the object to create a method and an apparatus of the genus mentioned with with objects, like metal parts, ceramic(s) disks, sheet metals, semiconductor chip, hybrid components, SMD circuits, seals etc. Features and defects of the surface, like edges, textures, kinks, color marks, matte sites, waviness, tears and. A. m., with high reliability and rate detected and classified to become to be able.

Illustration of the invention and their advantages

The solution of the object exists in the features of the claim 1. Other embodiments of the invention process are in the Unteransprüchen; an apparatus according to invention in claim 6 characterized.

The invention process exhibits the advantage that with this features and defects the surface of an object, like edges, textures, kinks, color marks, matte sites, waviness, tears and. A. m., with maximum possible signal to noise ratio and/or. with maximum contrast detects and independent from the respective picture environment pixelweise, D. h. for each point of surface separated, classified to become to be able, because the obtained information is contained in the temporal grey tone sequence in each case. By the complete provision of all lighting angles achieved becomes in advantageous manner that the features with matched filters and/or. Match OD filters extracted to become to be able.

With ring, sector or ringsektorförmigen distributions of the lighting functions and if becomes used as characteristic analysis a Fourier or a similar transformation, a rotationsinvarante classification of the features obtained becomes favourable. With an interpretative program then the result of the DFT operation can become graphic shown and the different error classes in - periodic (D1> D2) or 2-periodische (D1< D2) or nonperiodic with small changes in the grey tone sequence (large D0, small D1+D2) or continuous dark (all spectral values small) grey tone sequences discriminated become.

If the surface strews isotropic, then circle-symmetric lighting sequences to the rotationsinvaranten classification of directed features (Fig are. 2) convenient. However if the surface structure, rotationally symmetric for the example by directed processing, is like loops, no longer, then the use of elliptical lighting functions can be favourable for the optimum signal separation from surfaces and sought feature. Structure orientation must be to the alignment of the ellipse principal axes known, which before with test lighting functions certain can become.

In advantageous manner the single light sources can be within the lighting sky, (the preferably spherical is and on arbitrary flat sources of light, point or line to be can), by color sources of light replaced, preferably by three color sources of light green, red and blue. In this way the effort of the image pickup around the factor 3 at least reduced can become, because a color image corresponds to a sequence of at least three grey pictures.

The implementing the method favourable-proves the origin of the lighting coordinate system becomes placed into that point light source, which becomes imaged over the object plane thought as mirrors into the source of camera and so that to the bright field leads. Smaller tilting of the object plane can become by a relative translation of the lighting configuration with small effort corrected, since the lighting arrangement is cartesian and thus translation invariant.

▲ top To understand the method the viewing of the generalized lighting image fig. I (x, y, xi, phi) is helpful, those the connection between the brilliance matrix L (xi, phi) and the picture matrix B (x, y) and the entire photo-metrical information over the object describes contains, which can become at all gained with the inventive apparatus. The lighting array allowed it to produce the 4-dimensionalen lighting image space I (x, y, xi, phi) in a discrete form I (x, y, l, j). Light spot for light spot becomes driven and the resultant in each case image into the image memory deposited. With an user interface different projections or cutting planes can become this 4-dimensionalen of data area viewed.

For the pixelweise examination of the object surface of an object the local, D plays. h. for fixed x and Y-coordinates gained strewing, reflection and shade characteristic a crucial role. A matte spot, that the strewing club broadened, has an uniform strewing characteristic without prefered direction (isotropic strewing characteristic). Points of a direction-controlled surface feature are characterised by an anisotropic strewing characteristic and differ from such with Isotropic strewing characteristic. For example strews one point of surface, which belongs to a directed surface feature (scratches or edge) main the light into the video camera, which arrives vertical to its orientation. A point, that the inclination of the reflective surface changed, prefered stray light from a certain sector the single light spot of the lighting sky a bright grey value in the video camera, generated brilliance matrix with one error point with tilted specular surface.

By the invention process now Images with as small a redundancy and maximum logical value as possible can become generated. Bright field and dark field lighting are suitable as concepts for the extraction of the surface features in the simplest case, whereby that lighting function becomes a selected, which supplies a maximum contrast for the source of error. An optimum lighting filter becomes obtained, as the strewing characteristic becomes construed as lighting function. Like that for example the bright field lighting with a point source is a matched filter for a ideal-specular point of surface, at which the grey tone result of a camera maximum precipitates, with each other surface structure however drops. At points of surface with strong anisotropic strewing characteristics, as scratch or edges, which usually arises with different orientations, becomes from a direction vertical the orientation of the object characteristic illuminated, so that the brightness signal is stronger in the camera significant, as with an illumination from other directions. Paths of the directionality of the strewing characteristic thus an optimum lighting filter is only in the ply to detect anisotropic controlling features in a particular direction. Therefore lighting sequences become from a variety of solid angles used in this case. In addition the brilliance matrix in sectors becomes divided, which become successively driven. Thus rotation-invariant become and/or. of the orientation of the object of independent results obtained, because between several kinds of strewing characteristics discriminated can become.

If an hollow mirror, in particular parabolic mirror, becomes used as apparatus the formation of the dome shaped lighting sky, then this possesses the advantage that due to the illustration laws the reflected light beams, like for an localindependent scattering required, more or less horizontal of the parabolic mirror, run toward to the focal point and to the object parallel or more or less parallel, so that the virtual distance is that diffuse lighting up light sources of the object very large and can in first approximation as practical infinite apply. More or less vertical beams incoming on the object is however konvergeht, so that the light sources become imaged over the object surface thought as specular plane into the plane of the camera pupil. Thus (as particularly with the reflection light module realized for it) specular surfaces can become uniform in the bright field illuminated. This particular matching the virtual distance of the light sources can become varied: The distance of the lower light sources, like LED arrays, of the parabolic mirror is crucial for the jet formation, which arises on the object in the focal point whether it concerns thus convergent, divergent or parallel light,

why the distance is favourably variable. The locus of the point light source, those in the focal point parallel light generated, is a Paraboloid or a similar formed. Convergent one and/or. divergent light becomes generated in the focal point if itself the light source below and/or. above the locus finds; parallel light to the focal point becomes generated, if the light source is on this locus.

An other advantage consists of the fact that the apparatus is extremely compact. The hollow mirror can exist the other preferably integral made of transparent glass or plastic without recess and be unverspiegelt in its highest area to the formation of a passage opening for the reflektorischen illumination serving the light of the lighting device.

Short description of the drawing

It shows

Fig. 1 a schematic cross section by an illuminating device for the execution of the invention process in a lighting sky in form of an hemisphere and

Fig. 2 a plan view on the lighting sky to the illustration of the different selectable sectors, in which in each case or can be a plurality of light sources

Fig. 3 an algorithm of a flow diagram for pixel classification with (N+2) illuminations

Fig. 4 a schematic cross section by an illuminating device existing from a in two dimensions curved lighting sky with a lighting arrangement and

Fig. 5 an other illuminating device with in two dimensions curved lighting sky and a formatively different lighting arrangement and object supply.

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Embodiment of the invention

Over a basis 8 (Fig. 1) an hemispheric lighting sky, in which a variety of light sources 2 disposed are, curves preferably in different sectors sm, in accordance with n the Fig. 2 divided, whereby the light sources are easily programmable in their intensity single. The other a lighting module in the lighting sky, which exhibits a plurality of light sources 4, is, which are preferably disposed as cartesian array. Before the lighting module 3 is an optic 5, which bundles from single or from few light sources 4 emitted light such that it is 1 suitable to the uniform bright field illuminating more planar, reflective surfaces. The lighting module 3 serves in particular for the ripple and break examination of reflective surfaces and thus for the classification of surface inclinations. The light sources 2 serve for the diffuse illumination.

Of the light sources 2 and 4 on the object 1 thrown and light reflected strewn of this and by a lens 6 of a video camera and on CCD matrix is caught the video camera passed; the CCD matrix 7 is 9 connected to a bit map memory mechanism, which stores the grey screen sequences. After storing a certain, predeterminable number of images and/or. The image contents are subjected a 2D-Fouriertransformation, to color images within a bit map memory mechanism 9 of the video camera concerning the lighting coordinates of a fourier transformation, preferably in order to determine amount and phase of the lighting angle dependence of the single pixel.

This classification method develops on the peculiarities in principle of the grey tone sequence, which become obtained with passes of in some sections illuminations. The grey tone sequence becomes as finite cutout of a periodic, time and worth-discrete function regarded, which can become decomposed into their base components; Amount and phase of the components become by discrete fourier transformation (DFT) of the number N of grey values of the sequence obtained.

The sector number of N should be thereby for the fourier transformation a power of 2 and depends in accordance with the scanning theroem of the relevant strewing characteristic most complicated by the period: N @ 2x 2/Tmin

If one has it also - to periodic phenomena to do, illuminated must become with at least four sectors. For N=4 thus for example the grey tone sequences can be submitted by illumination from four space sectors gained and a subsequent fourier transformation. The results of this procedure for three error classes are subsequent shown and can be described as follows:

(A) The grey tone sequence of a scratch is - periodic (2 maximums), since the light becomes from 2 vertical lighting sectors located to its orientation scattered into the camera. The amount spectrum points large 2. Component up, the phase of the 2. Component 2 indicates the orientation direction of the feature.
(B) The grey tone sequences of a point is 2-periodisch, since he strews the light from a certain lighting sector into the camera. The amount spectrum has a large 1.Komponente.
(C) An isotropic strewing object material (mirror, spot) has a constant grey tone sequence. Its amount spectrum consists only of a standing dc component, which represents a measure for the strewing intensity.

Subsequent one is a spectral analysis of three exemplary grey tone sequences shown, whereby the horizontal coordinate describes the azimuthal lighting angle.
EMI9.1

With the help of the fourier transformation now one point of surface can and/or. a pixel of the image of the video camera classified becomes, whereby a subsequent possible algorithm according to invention in form of a flow diagram for the rapid hierarchical classification in for example four idealized error classes, like mirrors, point, scratches and spot, shown are. An intact point of the surface (mirror point) can be selected immediately, as light and Dunkelfeldbild become also drawn in considerations. In this case the classification without the fourier transformation is terminated.
EMI10.1

In accordance with the Fig. basis a lighting sky over a plane 35 or, which is preferably a innenverspiegelter parabolic mirror 11 or a innenverspiegelter mirror with paraboloidischer form, curves 4 or similar in two dimensions curved is and which, preferably in the highest area of the camber, an aperture possesses 12 to light-depressed; this aperture can consist also of a unverspiegelten, transparent material field of the mirror.

For less accurate characteristic extractions the lighting sky can be hemispheric in two dimensions curved adapted for best characteristic extractions.

Below the aperture 12 of the mirror 11 an object 10 which can be analyzed is on a transparent support 13.

Below the carrier 13 a lighting device 14 on the plane 35, which consists of a plurality of cartesian source of light fields 15, 15 min, 15 min min, is, whereby each source of light field exhibits a plurality of single light sources 17, 17 min. The source of light fields 15, 15 min, 15 min min are preferably LED arrays, whose single light sources are sequentially controllable 17, 17 min single or in groups. Direct above the source of light fields 15, 15 min, 15 min min the same taking off diffuser can be disposed, which is a low pass and serves for it that the light sources are localcontinuous, In order to fulfill the scanning theroem.

The lighting device above the mirror 11 and the aperture 12 consists of at least a reflection light source 23 and is
▲ top preferably likewise an LED array, which is an optic 25 to the reflektorischen illumination of the object (10) from a limited solid angle upstream and can before that likewise a diffuser 24 be. In the beam path of the optic located of the lighting device 23 emitted light beams 32 is for example a collimating lens 25, after which a divisor mirror 20 follows. The lateral divisor mirror is a video camera 21 disposed with bit map memory mechanism, which can exhibit an optics screen mechanism 22. The lighting device 23 and the video camera 21 are such one on the other tuned that the convergence of the light beam 32 is the same convergence of the observation light bundle 32 min.

The lighting device 23 serves the more or less vertical illumination of flat, reflective objects, whereby the light beam 32 by the collimating lens 25 arises and after passing the divisor mirror 20 as well as the aperture 12 within the mirror 11 as convergent light beam on the object 10, from there reflected and by the divisor mirror 20 on the video camera 21 is thrown. The lighting device 23 works analogue in Fig. 1 described lighting device 3.

By the single light sources 17, 17 min of the source of light fields 15, 15 min, 15 min min becomes light beam 19 the mirror 11 sent, which falls from there as parallel light beams 19 min on the object 10, which is in the focal point or approximate in the focal point of the mirror 11. These more or less horizontal incoming light beams 19 min become scattered and 21 directed by the divisor mirror 20 on the video camera. From above however convergent light arrives on the object 10, so that the apparatus according to invention the theoretical premisses for the simultaneous presence of horizontal, parallel lighting light beams and of vertical, convergent lighting light beams equally satisfied.

Alternative one can run instead of the camera path of rays the illumination beam path bent; alternative to the lens can be also a mirror for collimation present. Likewise the object surfaces brought in bright field can be spherical curved, if the collimation optics is corresponding adapted.

Fig. a modified lighting device 26, existing from a plurality of cartesian source of light fields 28, shows 5 28 min, like the source of light fields of the Fig. 4 constructed to be can. The source of light fields 28, 28 min are likewise 30 covered with a diffuser. The lighting device 26 as well as the diffuser 30 point central per a recess 29 and/or. 31 up, shifted by which a slide can become 33 with the object which can be detected 10 in vertical direction. By a simple height and side adjustable thus the object can become 10 and also horizontal corrected vertical concerning the focus of the mirror 11 if necessary. Otherwise the embodiment of the mirror as well as the lighting device 23 and the video camera of 21 those corresponds to 11 the Fig. 1.

The size and number of the optimum required sectors depend on the object function with the lowest half width. The suitable sector number can be found, as the ratio between characteristic signal and surface signal over the number of the sectors becomes applied. Usually a rapid saturation points itself to a steep increase; already with 3 to 8 images powerful error detections can be realized, which are opposite static illuminated frames from substantial advantage. List of the numerals 1 object
2 light sources
3 lighting module
4 light sources

5 optic
6 lens
7 CCD matrix
8 object plane
9 bit map memory mechanism of the video camera
10 object
11 mirror
12 aperture
13 transparent supports
14 lighting device
15, 15 min, 15 min min of planar source of light fields
16 movement double arrow
17, 17 min single light sources
18 diffuser
19 light beams of a single light source to the mirror
19 min of the mirror reflected light beam of a single light source
20 divisor mirrors
21 video camera with bit map memory mechanism
22 optics screen mechanism
23 lighting device
24 diffuser
25 optic, z. B. Collimating lens
26 lighting device
27 movement double arrow
28, 28 min planar source of light fields
29, 31 recesses
30 diffuser
32 light beams
32 min observation light bundle
33 slides
34 movement double arrows
35 plane

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1. Method to lightingdynamic recognizing and classifying surface features and - defective object (1), whereby detecting surface by means of several illumination sources (2, 3) illuminated becomes, which have a different positioning in the space and which illumination sources sequentially the object illuminated and diffuse In each case the back-thrown or reflected light of the surface in each time by means of a video camera (7), which a bit map memory mechanism (9) exhibits, when spatiotemporally different images become received, characterised in that the object (1) of a lighting sky surrounded is more arbitrary, whose laminar source of light arrangement (2) can be programmed with predeterminable angle and intensity gradation free, by means of the same a variable number Light functions generated it becomes which become the object successively illuminated and the object additional from a limited solid angle range with an other programmable light source (3) over a collimation optics so illuminated that for all points of a planar object surface the reflection angle condition satisfied will and a suitable selected point source becomes imaged over as plane mirror the meant surface into the camera pupil, and which resultant images are submitted of 7) received and in a bit map memory mechanism (9) stored and the grey tone sequences of the received picture pile of a characteristic analysis by the video camera (.

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2.Verfahren according to claim 1, characterised in that the lighting functions elliptical ring, sector or ringsektorförmige distributions exhibit and the characteristic analysis a Fourier or a similar transformation are, the one rotation-invariant classification of the features effected.

3. Process according to claim 1, characterised in that each light source within the lighting sky from a plurality of separated controllable color sources of light, preferably green, red and blue, exists and simultaneous ever an image with the different superposed colors received becomes, whereby a color image of at least in each case three successive grey pictures replaced.

4.Verfahren according to claim 1, characterised in that to the compensation or measurement of a slight tilting of the object plane the origin of the lighting coordinate system into that point light source placed becomes, which becomes imaged over the object plane thought as mirrors into the camera pupil and so that to the bright field leads.

5. Process according to claim 1, characterised in that the algorithm of the hierarchical error classification with fourier transformation as follows is:
EMI17.1

6.Vorrichtung for lightingdynamic recognizing and classifying surface features and - a defective object (1), whereby the surface which can be detected is illuminable by means of several illumination sources (2, 3), which have a different positioning In the space and which is receptible illumination sources sequentially the object to light up and diffuse in each case the back-thrown or reflected light of the surface in each time by means of a video camera (7) and a bit map memory mechanism (9) as spatiotemporally different images, characterized by the subsequent features:

a) a lighting sky (dome) from a variety of free programmable light sources (2), which are summarizable into arbitrary formed lighting functions, which serve for the sequential illumination of the object from predeterminable solid angle ranges,
b) at least a programmable light source (4) with a lens or a reflecting optics (5) to the uniform reflektorischen bright field illumination of planar or weak curved surfaces,
c) an algorithm generator, that the picture received of the video camera and/or. Color picture pile of a transformation of subjecting is capable, with which with appropriate choice of the lighting function the sought surface features and type of error with maximum signal signal-to-noise ratio are more detectable and classifyable.

7.Vorrichtung according to claim 6, characterised in that the lighting functions from a number of Ringsektoren (sm, n) exist, of them thereby generated grey tone screen sequences of a 1D or 2D-Fouriertransformation concerning the lighting coordinates and/or. the Ringsektorindices m and n to be subjected, whereby becomes performed by means of the obtained coefficients a rotationsinvarante classification of the features.

8.Vorrichtung according to claim 6, characterised in that of the lighting skies inside more verspiegelter, concave curved hollow mirror (11) is, which exhibits a recess (12) in its highest area, above the same the lighting device (23), serving for the reflektorischen illumination, is and that the lighting device serving for the diffuse illumination (14, 26) from planar source of light fields (15, 15 min, 15 min min;) exists 28, 28 min, which are underneath the hollow mirror, whereby the object (10) below the recess (12) and approximate central within the planar source of light fields within the tie point and/or. the collect-flat of the hollow mirror disposed is.

9.Vorrichtung according to claim 8, characterised in that of the hollow mirrors a parabolic mirror (11) is and itself the object (10) in the focal point and/or. more approximate within the same finds.

10. Apparatus according to claim 8, characterised in that of the hollow mirrors a Kugelspiegel or an ellipsoid mirror or a similar curved mirror is and itself the object (10) in the burning and/or. Center and/or. more approximate within the same finds.

11. Apparatus according to claim 8, characterised in that the source of light fields planar LED arrays (15, 15 min, 15 min min; 28, 28 min) is, and the covered disposed on a common plane (35) underneath the hollow mirror with a diffuser (18, 30) is.

12. Apparatus according to claim 8 or 11, characterised in that between the source of light fields (15, 15 min, 15 min min) and the hollow mirror (11) a transparent support (13) for placing the object (10) disposed is.

13. Apparatus after one of the previous claims, characterised in that the lighting devices (14, 23, 26), in particular the LED arrays (15, 15 min, 15 min min; 28, 28 min), free is more programmable.

14. Apparatus after one of the previous claims, characterised in that the lighting device (23), serving for the reflektorischen illumination, of an LED array consists, before which a diffuser is and above the recess (12) of the hollow mirror (11) a divisor mirror (20) disposed, which leads the light reflected of the object (10) on the video camera (21).

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